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(71) Applicant (*for all designated States except US*): IMPERIAL CHEMICAL INDUSTRIES PLC [GB/GB]; Imperial Chemical House, Millbank, LOndon SW1P 3JF (GB).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): NOAKES, Timothy, James [GB/GB]; The Hollies, Llyn-y-Pandy Lane, Pantymwyn, Nr Mold, Clwyd CH7 5JF (GB). GREEN, MIchael, Leslie [GB/GB]; Tai-Cochion, Village Road, Nannerch, Clwyd CH7 5RE (GB). JEFFERIES, Andrew [GB/GB]; The Hollies, Llyn-y-Pandy Lane, Pantymwyn, Nr Mold, Clwyd CH7 5JF (GB). PRENDERGAST, Maurice [GB/GB]; 11 Bellingham Drive, Runcorn, Cheshire WA7 4XN (GB).

(74) Agents: COLLINGWOOD, Anthony, Robert et al.; ICI Chemicals & Polymers Limited, Intellectual Property Dept., P.O. Box 11, The Heath, Runcorn, Cheshire WA7 4QE (GB).

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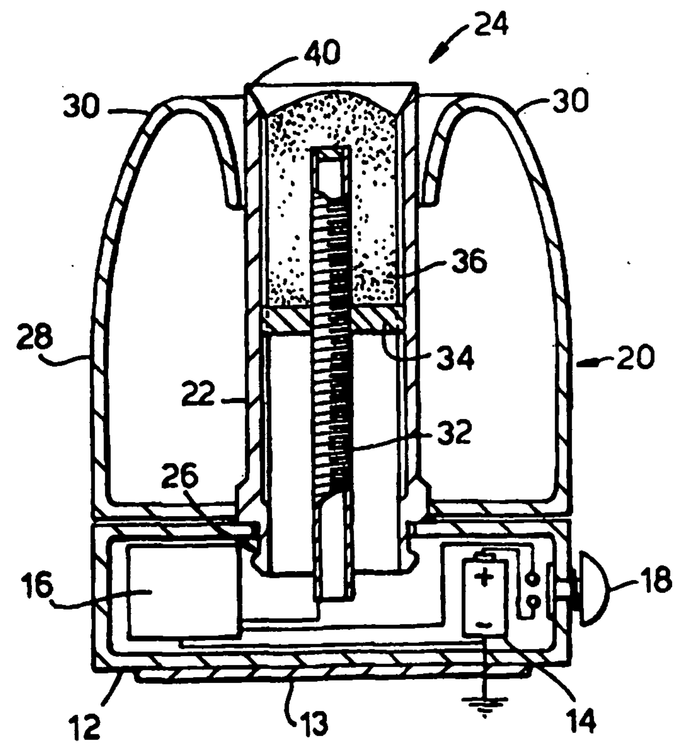
(57) Abstract

A method and device (20) for spraying particulate materials in which a high voltage is applied to a mass of the particulate material so as to cause particles to issue from the mass. High voltage from a source (16) is applied to a mass of material (36) stored in a container. A surface of the mass (36) is exposed to the surroundings and the applied voltage is conducted through the bulk material to particles located at the exposed surface which are thereby projected as an electrically charged spray from the mass under the influence of the electric field substantially without any accompanying corona discharge.



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ELECTROSTATIC SPRAYING OF PARTICULATE MATERIAL.

This invention relates to electrostatic spraying.

There are a wide variety of methods available for effecting the dispensing of liquid-based materials. For instance, aerosol-type dispensers are in widespread use. Such dispensers are particularly convenient for dispensing personal care and personal hygiene formulations (eg perfumes, deodorants, cosmetics etc). Often in such applications, the active ingredient is in fact a solid material suspended or otherwise dispersed in a suitable liquid carrier to aid dispensing.

According to one aspect of the present invention there is provided a method of spraying particulate materials comprising applying a high voltage to a mass of the material in such a way as to electrically charge particles of the material and thereby effect propulsion of the particles away from said mass.

According to a second aspect of the present invention there is provided a method of spraying particulate materials comprising applying a high voltage to a mass of the material in such a way as to electrically charge particles of the material present at and/or in the vicinity of a surface or surfaces of the mass and and thereby generate an electric field by means of which the particles are caused to issue from such surface(s).

A feature of the invention resides in the absence of any liquid vehicle for suspension of the particulate material. Also high voltage is applied to the mass of particulate material prior to issue of particles from the mass.

The use of electrostatic fields in the spraying of particulate materials is known *per se*. For instance, as discussed in International Patent Application No. WO 94/19042 (Balachandran *et al*), it is known that the site of deposition within the respiratory tract of an inhalable substance can be influenced by the level of electrostatic charge on the particles of the inhalable substance. International Patent Application No. WO 94/19042 discloses a device in which the substance to be administered is dispensed in the form of inhalable particles (aerosol liquids or powder) into a passageway defined by a mouthpiece of the device and an arrangement of electrodes within the passageway is used to impart electrostatic charge to the particles so dispensed. In this way, the electrostatic charge characteristically imparted to particles on being dispensed from a particular type of dispensing means can be modified in a controlled manner as they pass through a charging region established by the electrode arrangement. Such modification is stated to encompass increases, reductions, reversal and neutralisation of the level of electrostatic charge on the particles.

With such an arrangement, it is difficult to secure a uniform level of electrostatic charge on the particles since the particles are dispersed into the inhaled airstream and passed through the electric field developed by the electrodes. Particles at different locations in the airstream therefore tend to receive difficult levels of electrostatic charge resulting in particles with a wide spectrum of electrostatic charge.

Also electrostatic spraying is used in coating articles with plastics material, the material initially being sprayed onto the article as a relativley thick layer and then consolidated to form a continuous layer by heating. The particulate material is fluidised and caused to flow by means of an air supply and is electrically charged by traversing a corona discharge electrode after being fluidised. In such coating techniques, the particulate material used has a high volume resistivity (typically 10^{14} ohm.cm and higher) and is not capable of being sprayed if voltage is applied to a mass of such material, ie since conduction of the applied voltage and charge leakage through the mass is largely prevented by the highly insulating nature of the material. Non-conduction of the charge is highly desirable since such spraying techniques are usually required to produce relatively thick adherent, coatings of material and the non-conduction of charge (ie lack of charge dissipation) is an important factor in ensuring that the material adheres to the target for the significant time period between spraying and subsequent heating and consolidation of the deposited particles.

In contrast, in the method of the present invention, the particulate material will tend to be of lower resistivity than used in the article coating methods just referred to in order that the particles can be charged by leakage of charge through the mass (rather than by means of a corona discharge). The ability of the particulate material to adhere by means of electrical forces will tend to be lower but, in general, the thickness of the layer to be deposited will tend to be substantially less and, where gravity may be a factor, in terms of adherence reliance is placed on the dampness or tackiness of the surface on to which the particulate material is sprayed. Also, in practising the methods of the present invention, it is unnecessary to produce a flow of gaseous fluid to effect transport of the particulate material. Instead the electric field is instrumental in propelling the particles.

As mentioned above, because of the lower resistivity employed in practising the present invention, adherence to surfaces by virtue of the electrical forces created tends to be reduced since charge leakage or dissipation can occur. The reduced adherence may be compensated for if the surface to be sprayed is damp or tacky. In some cases, the retention of the sprayed particulate material may be assisted by application of some form of adherence promoting agent to the surface to be sprayed and/or to the particulate material.

The mass of particulate material may be contained within a receptacle having a discharge outlet at which a surface of the mass is exposed at least during spraying.

The applied voltage may be positive or negative (positive voltages being preferred) and is typically in the range of 3 to 40 kV, usually less than 30 kV, eg 3 to 25 kV. An important feature of the invention is that the voltage is selected with the aim of preventing or miminising corona discharge. Thus, if the device is put into its operational state in the absence of the particulate material, the voltage selected is such that , without said mass present, there is substantially no corona discharge from the device. In the present invention, corona discharge is considered undesirable in contrast with the prior art where corona discharge is important.

In some instances, it may be desirable to use a high voltage generator producing an output which alternates between positive and negative polarities, for instance for shock suppression purposes or to allow the spraying of targets which are otherwise difficult to spray electrostatically (for example, hair - especially dry fine hair) as disclosed in our prior EP-A-468735 and 468736 and PCT-A-WO94/13063, the disclosures of which are incorporated herein where the context admits. Other features of our prior EP-A-120633, 441501, 482814, 486198, 503766 and 607182 may be employed in practising the present invention and the disclosures of these patent specifications are also incorporated herein where the context admits.

The high voltage generator may be of the type disclosed in EP-A-163390. However, voltage generators of this form are expensive to manufacture and are relatively bulky especially for use in electrostatic spraying devices required to be compact in size, eg sprayers for cosmetics, perfumes and medical and pseudo-medical formulations such as ocular, oral and nasal formulations and skin treatment agents.. Moreover, the battery pack required for power supply must be accommodated within the housing of the sprayer and frequent battery replacement or recharging is necessary.

Accordingly in the present invention the voltage generator may be one comprising a large array of voltage producing elements interconnected to produce a high voltage.

Preferably the generator is a solid state device comprising hundreds or even thousands of individual voltage producing elements which may be serially connected so that collectively they produce a high voltage output.

Typically the current output of the generator will be such that the power rating of the generator is 100 mW or less, more usually 50 mW or less. For example, for a paint spraying device, the voltage may be in excess of 25 kV and the current of the order of 1 microamp (power rating of 30 mW) whilst for a room fragrance sprayer the voltage may be of the order of 0.5 to 2.0 mW, typically 1.2 mW (eg 100 nA current and 12 kV voltage).

The high voltage generator conveniently comprises an array of photosensitive elements so arranged as to produce a voltage output of at least 1 kV.

Preferably the array of photosensitive elements is so arranged as to produce a voltage output of at least 5 kV, and more preferably upwards of 8 kV.

The generator is conveniently in the form of an electronic solid state device comprising a large array of photosensitive elements. For instance, the solid state device may comprise a photovoltaic material (eg suitably doped polycrystalline silicon such as that used in the production of solar cells and solar panels) appropriately divided into discrete sections, eg by etching and/or laser scribing techniques commonly used in the production of semiconductor devices, to form a large array of discrete photovoltaic elements interconnected in such a way as to produce, collectively, a high voltage output of the order referred to above when irradiated.

A cell of photovoltaic material, such as silicon doped with boron to produce a pure lattice of p-type material, can produce a relatively low voltage output (typically of the order of 0.45 V) when

illuminated depending on the light intensity and load, but independently of the surface area. Current output on the other hand is related to both light intensity and the surface area of the cell. For the kind of electrostatic spraying applications with which the present invention is primarily concerned, current demand is very low (microamps and even nanoamps) and consequently, by serially connecting a sufficiently large array of low voltage output photovoltaic elements consistent with the high voltage to be secured (eg several kV and greater), it is feasible to obtain sufficiently high voltages for electrostatic spraying applications without requiring the large surface areas usually associated with solar panels.

The voltage producing elements may be constituted by light sensitive elements, such as photovoltaic elements, connected in an array which is so disposed as to be irradiated by ambient light. In this case, the array may be located on an external part of the spraying device embodying the generator so as to be exposed to the surroundings. This embodiment may for instance find utility for room fragrance spraying since the generator may be active when the array is illuminated during daylight hours (and night time when the room lighting is switched on) but is deactivated during the hours of darkness when the room lighting is switched off.

Means may be provided for selectively exposing and shielding the array to/from ambient radiation/light according to whether high voltage output is required. For instance, the housing of the generator or spraying device may be provided with a sheath or other radiation shielding device movable between positions in which it conceals or exposes the array to the surroundings. The shield may alternatively be in the form of a removable cover which, when mounted on or attached to the generator or spraying device, prevents irradiation of the array, and allows irradiation when removed, the switching action thereby being effected by removal and replacement of the cover.

The shield/cover may be adjustable to vary the extent of exposure of the array and thereby vary the rate of spraying for instance.

Where the spraying device is designed for hand-held use, the device may comprise a portion intended to be held in the hand, eg a hand grip, and a section which would not normally be encompassed by the hand in use of the device, the array of photosensitive elements being disposed on the latter section so as to be exposed to ambient radiaton/light.

When the array is arranged on a section of the device so as to be exposed in use, the array may be protected from damage by a superimposed layer or cover of material which is at least partially transmissive to the radiation/light.

In another embodiment, the voltage producing elements are constituted by radiation sensitive elements connected in an array arranged to be irradiated by a radiation source forming part of the spraying device. The radiation source may constitute the sole or primary source of radiation for the array or it may serve to supplement ambient radiation/light. For instance, the radiation source may be a radiation emitting element such as a light emitting solid state element (eg a light emitting diode), a filament (eg light bulb) which emits light when current is passed through the filament or a fluorescent lamp. Switching on and off of the generator in this instance

may be controlled by switching the radiation emitting element on and off, in which case the switching device need only be a low voltage switch controlling a high voltage output. Alternatively switching on and off of the generator may be effected by means operable to expose and shield the array selectively to/from the radiation emitting element and such means may be movable by the user between exposure and shielding positions relative to the array.

Where the spraying device includes such a radiation source, the source may be connected to terminal means to which an electrical power source (such as a low voltage battery) is connectible. In this event, the housing of the spraying device preferably includes a compartment for insertion of the power supply and, if desired, the radiation source and the high voltage generator may be accommodated internally of the housing. Activation and deactivation of the generator may be effected by means of a user-controllable switch forming part of an electric circuit including the terminal means and the power supply (in use).

Exposure of the array (for example to control switching on and off of the generator) may be controlled by means of a user controllable actuator. In the case of a spraying device, the actuator may serve to control the supply of material to the outlet of the device and may also be coupled with a movable masking element so that, in response to delivery of the material to the spraying outlet, the array is exposed to produce high voltage for application to the material and thereby deliver a spray of electrically charged material. In a typical embodiment, the spraying device comprises a user operable trigger for applying pressure to electrostatically sprayable material contained in a reservoir or container (for example in the form of a piston and cylinder type device or in the form of a compressible container) to effect delivery of the material to the spraying outlet, and the trigger is coupled to a masking element which is moved relative to the array (translationally or rotationally) to expose or increase exposure of the array to ambient radiation or to radiation from an associated radiation source. Alternatively, the masking element may be omitted and the radiation source may be energised in response to actuation of the trigger whereby the array is irradiated in the course of operating the trigger to deliver the material to the spraying outlet.

If employed, the radiation source may serve a dual purpose, ie the production of light for irradiation of the photosensitive array, and for producing light for illumination of the object/target to be sprayed. In addition, the radiation source may serve to indicate that the generator is operational.

As disclosed in EP-A-468735 and 468736 and PCT-A-WO94/13063, it is desirable in some applications to provide a bipolar high voltage output, for example for the purposes of shock suppression and/or to allow the spraying of electrically insulating materials such as plastics, human hair etc, which are otherwise difficult to spray. The generator may for such applications be arranged to provide a bipolar output, eg with an output frequency as disclosed in EP-A-468735 and 468736. For example, the high voltage output of the generator may be electronically switched at a desired frequency (which may be user-controlled) by means of electrical circuitry associated

with the generator to produce bipolar output, eg using high voltage switching arrangements as disclosed in PCT-A-WO94/13063. Alternatively the generator may comprise two arrays of photosensitive elements, the arrays being configured to produce respective positive and negative high voltage outputs and control means being provided to alternately irradiate the arrays (either by ambient radiation/light or by radiation/light produced by an associated radiation source or sources) so that the composite output alternates between positive and negative values at a frequency determined by the control means.

In a specific embodiment, a spraying device may comprise two high voltage generators of the solid state type disclosed above with radiation responsive switching means of the form disclosed in International Application No. WO94/13063 arranged to alternately switch the generators in such a way that a bipolar voltage is applied to the location or site from which a spray or a stream of ions is to be generated, positive voltage being derived from one generator and negative voltage from the other. For instance, each generator may be coupled to said location through a respective radiation responsive switching means and control circuitry may be provided to operate the switching means in alternating fashion with a predetermined periodicity by controlling the radiation sources associated with each switching means.

The material is preferably one which in bulk form, as a packed particulate mass, is not highly electrically insulating, typically exhibiting a resistivity of about 10^{11} ohm.cm or less, usually in the range of 10^5 to 10^{11} ohm.cm. so that the voltage can be applied to the particles at the surface through the mass of material.

For the avoidance of doubt, the volume resistivity of the material *per se* is not necessarily within the specified range. What is important is that the resistivity of the bulk powder should be appropriate to ensure that voltage applied to the bulk material is conducted to the surface from which the particles issue as a spray. Thus, for example, it is conceivable that the particles could be composed of a core of highly insulating material with a volume resistivity well in excess of 10^{11} ohm.cm but coated with a material of lower resistivity such that the particles exhibit a bulk resistivity within the range 10^5 to 10^{11} ohm.cm when consolidated as a packed mass without compressing the packed mass. In some cases, the particulate material may comprise a mixture of materials having differing volume resistivities. For instance, where one material used alone is found not to spray satisfactorily, a mixture with a second material having a different volume resistivity may permit the combined materials to spray under the same voltage conditions.

Particles sprayable by methods in accordance with the present invention will usually have a mean particle size lying in the range of 1 to 1000 microns, typically less than 400 microns and preferably 10 to 200 microns. Preferably the particles are of a non-filamentary nature since elongate fibres or the like are more prone to corona discharge, with generally spherical particles being preferred.

Various applications of the method of the invention are envisaged, for example spraying of suitable powdered active ingredients for use in the following: